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The use of solar energy in the buildings construction sector in Spain

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Abstract

The recent commitment made by many countries to combat the harmful effects of fossil fuel energy has centered world attention on the implementation of policies geared towards an optimal energy performance and the use of renewable energies. The construction of buildings with sustainable energy systems necessarily plays an important role in such policies, given the fact that in 2005 more than 800,000 housing units were constructed in Spain, a country with more than 2500 h of sunlight per year. This article reviews the European and Spanish legislation regarding construction and renewable energies. Within this context, a description and analysis are given of the progress made by the construction sector in the implementation of new energy-related technologies with special emphasis on solar energy.

Keywords: Solar energy; Construction sector; Building

Contents

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1. Introduction

In the last five years there has been a spectacular construction boom in Spain. According to the National Association of Architects,[1] the number of new housing units in this period has doubled, going from 400,000 in 2000 to a record 800,000 in 2005.

Because of its geographic location, Spain has over 2500 h of sunlight per year, and is the European country with the third highest quantity of photovoltaic power, amounting to 11.7 MW p in 2004. However, when it comes to using solar energy for domestic activities such as heating water, Spain lags farther behind, only ranking eighth. This fact is significant because domestic energy use is intimately related to the construction sector [1]. Spain's low ranking here means that the country still has a long way to go to fully benefit from this type of energy, and that greater use should be made of solar power in the design and construction of houses.

It is our assertion that in a national context in which there is a record-breaking number of new housing units built every year, it is crucial to see exactly how the issue of energy supply is presently being dealt with. The construction boom in Spain also comes at a time when an increasing number of voices are being raised in favor of the development and construction of sustainable housing [2].

There are a wide range of possible measures that could be taken to foment the use of renewable energies [3]. One possibility would be to oblige architects and developers to include a set of minimum requirements for efficient energy use in the project designs of new buildings, as well as to inform the purchaser and/or client of the contents of European Directive 2002/91/EC on the Energy Performance of Buildings [4].

In this article, we analyze European and Spanish legislation that regulates the use of renewable energy in the construction of housing developments. We emphasize the fact that the legislative framework regarding construction will soon experience significant modification in the near future with the passing of the *Código Técnico de la Edificación*[2] (CTE). The purpose of our study is to review the European and Spanish legislation concerning construction and renewable energies [5], as well as to describe the progress made by the construction sector in the implementation of new energy-related technologies with special emphasis on the use of solar energy.

2. Solar energy in Spain

Spain is located in the south eastern part of Europe (see Fig. 1). More specifically, it is situated in the temperate zone between latitudes 43°47′24″ N (Estaca de Bares) and

[1] In Spain this type of professional association is known as the *Colegio de Arquitectos*.
[2] Technical Building Code.

Fig. 1. The geographic location of Spain on the European continent.

36°00′3″ S (Punta de Tarifa); and between longitudes 7°00′29″ E (Cape Creus) and 5°36′40″ W (Cape Touriñan). It has a surface area of 580,850 km^2.

To the north, it is bordered by the Cantabrian Sea, France, and Andorra; to the east, by the Mediterranean Sea and the Atlantic Ocean; to the south, by the Atlantic Ocean; and to the west, by the Atlantic Ocean and Portugal. Although Spain is located in a temperate zone, it has the following climate distribution [6] (see Fig. 2):

- *Oceanic climate*: Galicia and the Cantabrian coastline. These areas have mild temperatures and abundant rainfall.
- *Mediterranean climate*: the Mediterranean coastline. This climate is characterized by hot, dry summers, little rainfall, and mild winters. Rainfall is generally more frequent in spring and autumn, when a cold air pool may occur, resulting in intense torrential rains. Periods of drought alternate with periods of abundant precipitation.
- *Highland climate*: the Pyrenees, the *Sistema Central*[3] and the Penibetic Mountain Range. Winters are long and cold with abundant rainfall.
- *Continental climate*: the interior of the Iberian Peninsula. This area has cold winters and hot summers because of its distance from the coastline. Storms frequently occur during the summer months.
- *Subtropical climate*: the Canary Islands. The temperatures are mild throughout the year with relatively low levels of precipitation.

Thanks to its geographic location and climate, Spain is in a privileged position in comparison to other European countries since each square meter of its surface area receives 1500 kW h of energy. This figure is similar to that of many Central and South American countries. In fact, in various areas of Spain, there are over 2500 h of sunlight per year [7] (see Fig. 3).

[3]Mountain range on the Iberian Peninsula, consisting of several smaller mountain ranges, which is a primary feature of the Iberian plateau (*Meseta Central*).

Fig. 2. Climate distribution in Spain.

From the beginning of civilization, men have resorted to bioclimatic architectural methods to significantly reduce and even eliminate the need to artificially heat/cool their homes and light them during the day. With a view to taking greater advantage of sunlight, they would design houses whose windows, doors, balconies, facades, and patios faced the south. They would build glassed-in porches and huge fireplaces to light inside areas. They would whitewash door and window frames to enhance the sensation of brightness, and would use skylights and glassed-in balconies as solar collectors. They tried to mitigate the unpleasant effects of excessive sunlight (glare and heat) in the inside of houses by making roofs overhang significantly and by prolonging the cornices on windows and entrances. They protected balconies by means of small projections that acted as shade. Decorative grille work and wooden lattices were placed on windows to filter out sunrays. Transoms and openings were put above front doors for better ventilation. Porches were protected with trellises, and high walls shielded the grounds surrounding the house [8].

Without recurring to any other device, such buildings made passive use of solar energy through the suitability of their location, design and orientation, the correct use of the physicochemical properties of materials, as well as architectural elements such as soundproofing, insulation, type of covering, protections, etc. However, such measures, though useful, are no longer sufficient in themselves. It is now time to branch out to a wider and more active use of solar power by capturing thermal energy (heat) with solar sensors or by generating electricity with photovoltaic cells [9].

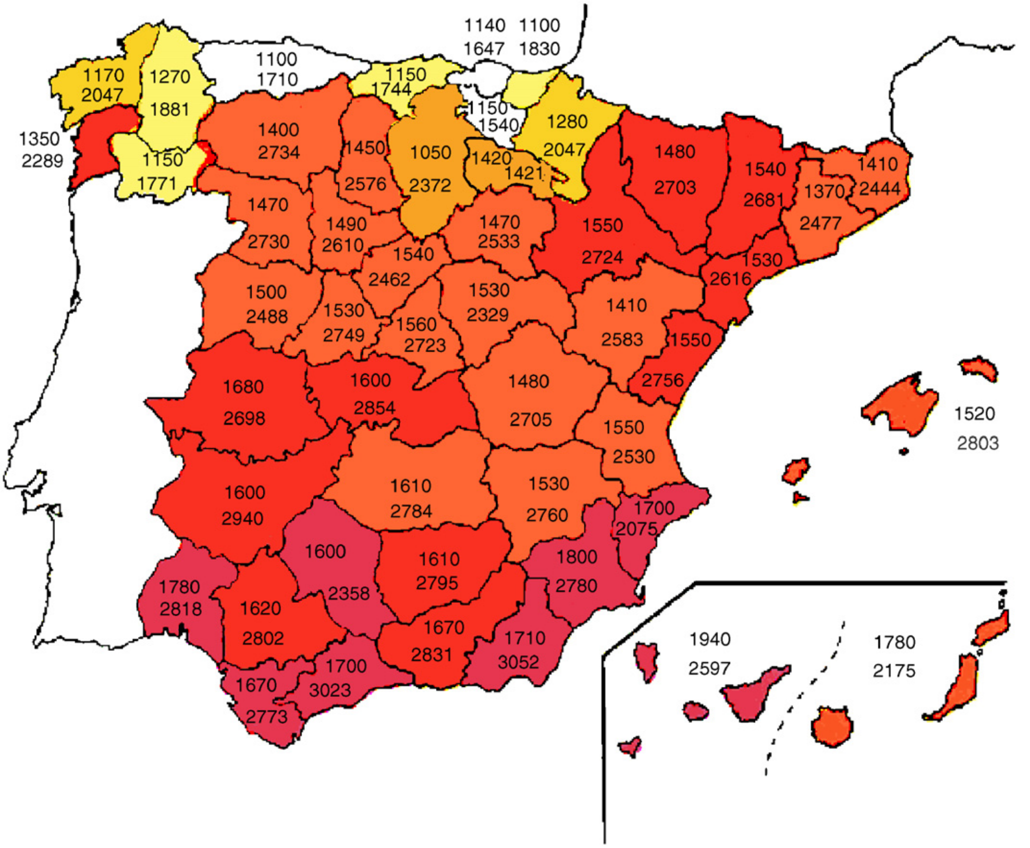

Fig. 3. Energy in kW/h/m^2 surface area per year/hours of sunlight.

3. Legislation regarding construction

3.1. Europe

In order to promote and encourage the use of solar energy, in December 1997 the European Union passed the *White Paper for a Community Strategy and Action Plan. Energy for the Future*: *Renewable Sources of Energy*, and proposed as an objective for 2010 that renewable energies supply 12% of the primary energy demands of the European Union [10].

The European Union Green Paper entitled *Towards a European Strategy for the Security of Energy Supply*, specifically states that one of its priorities is the integration of renewable energies in new constructions through regulations obliging heating and air cooling systems to necessarily depend on these energy sources [11].

In the case of solar thermal energy, the EU White Paper seeks to increase the number of sensors from 6.5 square meters in 1995 to 100 million square meters in 2010 [12]. The purpose of European directive 2002/91/CE is to encourage the use of solar photovoltaic

and thermal renewable energies [13]. In this sense, important considerations are external climatic conditions and local characteristics as well as the environmental requirements and the cost-efficiency relation. One of the major objectives here is to improve the energy performance of buildings since such structures have a significant long-term impact on energy consumption (heating and air cooling systems, water heating, and electricity) [14].

3.2. Spain

Legislation regarding construction has experienced important changes since the passing in 2002 of the European Directive on Energy Performance, 2002/91/CE and its transposition to Spanish law at the end of 2005 [14].

The plan to encourage the use of renewable energies has the same global objective as the European Union in its *White Paper on Renewable Energies*, which states that at least 12% of the total energy demand in Spain should be covered by renewable energy sources [15].

The *Ley de Ordenación de la Edificación*, Law 38/1999[4] of November 5, 1999 establishes three sections of basic demands, which refer to the functionality, safety, and habitability of buildings. The habitability section regulates the economical use of energy and thermal insulation with a view to achieving rational energy use for the optimal functionality of buildings. This means reducing energy consumption to sustainable levels, and having at least a portion of this consumption come from renewable energy sources [16].

Within this context, there are new regulations which regard the following [14]:

- Minimum requirements of energy performance regarding illumination, soundproofing, insulation, heating, air condition, and sanitary hot water in buildings.
- Energy certification for buildings.
- Use of solar photovoltaic and thermal renewable energy.

The legal measures taken in Spain in response to these new demands are specified in the following laws:

(1) The CTE[5] that defines and establishes the basic requisites for safety and habitability that should be fulfilled by buildings, and which stipulates the requirements that must be complied with in the project design, construction, use, maintenance, and conservation of buildings with a view to enhancing their quality, guaranteeing the health and safety of occupants, and protecting the environment in the immediate surroundings [17].
This code establishes the following set of objectives
   - To limit energy demands through the optimization of building designs, taking into account all the techniques of bioclimatic architecture and passive solar energy. For the first time the CTE also includes energy performance criteria for lighting consumption.
   - To improve the performance of heating systems through the incorporation of inspections and audits of such installations, and providing solutions to make them more efficient.

[4]Law of Building Organization.
[5]Technical Building Code.

- To incorporate solar thermal energy for sanitary hot water. For new buildings this will be obligatory. Depending on the climate zones, between 30% and 70% of the energy demand for sanitary hot water should come from solar energy.
- To implement solar photovoltaic energy in building complexes with high energy consumption. Consequently, solar photovoltaic panels will be obligatory in hotels and hospitals (>100 occupants or beds), multimedia centers (>3000 m^2), office buildings (4000 m^2), hypermarkets (>5000 m^2) and fair pavilions (>10,000 m^2). This means installing power between 6.25 and 62.5 kW p. Moreover, all installations of up to 100 kW will be included in the current power rates of 0.4 euros/kW h. (Previously, this was only applicable to installations of up to 5 kW.)

(2) The *Plan de Fomento de las Energías Renovables*[6] (PFER) [18] describes the principal elements and guidelines that can be considered relevant in designing a strategy so that the growth of renewable energies as a whole can cover at least 12% of all primary consumption by 2010. However, this objective can only be reached if a greater percentage of such energies is used in buildings, and more specifically, in their heating systems, where energy consumption is the highest.

The *Reglamento de Instalaciones Térmicas*[7] (RITE) and its *Instrucciones Técnicas Complementarias*[8] (ITE) establish the requirements for heating systems in buildings. These regulations are in response to the public demand for thermal comfort and hygiene in heating, cooling, and sanitary hot water systems. The objective of these regulations is to promote a more rational level of energy consumption for economic as well as environmental reasons. In a parallel way, other considerations to be taken into account are the basic construction and design requirements for buildings. In the interest of economic viability, all of these factors must be maintained during an important part of the useful life of the structure [19].

These regulations are divided into two sections. The first section includes the RITE and the ITE. The second section, which is basically informative, is an annex of relevant documents for reference purposes. The following is a summary of the ITEs that explicitly mention renewable energies:

- *ITE 02.4.1. Design. Heating and cooling systems. General description*: According to this document, the choice of a heating and cooling system makes it necessary to examine the possibility of using subsystems of energy conservation and recovery as well as the exploitation of free/renewable energies.
- *ITE 02.4.12. Design. Heating and cooling systems. Electric Energy*: According to this document, in both residential and government buildings that use electrical energy by the Joule effect for heating, the global transmission coefficient of the building (K_G) should not be greater than the boundary value established for this energy source. This would be the case for buildings without heating or which are heated with electrical energy by the Joule effect, as stated in regulation NBE-CT concerning heating systems in buildings [20]. Premises excluded from this requisite, and which thus must comply with the conditions set out in case I (solid, liquid or gaseous fuels) are

[6]Plan to promote renewable energies.
[7]Regulations for thermal systems.
[8]Complementary technical instructions.

those using residual or free energy sources as well as electrical energy as an auxiliary energy source as long as the annual coverage of the residual/free energy source is more than two-thirds.

- *ITE 02.5.4. Design. Central production of sanitary hot water. Use of electrical energy for the production of sanitary hot water*: The use of *electrical energy for sanitary water heating* through the Joule effect in central sanitary hot water systems is permitted when it is used as a support for residual/free energy sources, and always as long as these sources cover more than two-thirds of the total energy demand.
- *ITE 04.9.1. Equipment and Materials. Boilers. General conditions*: According to this document, boilers not subject to *Real Decreto*[9] 275/1995 are those that run on solid, liquid and gaseous fuels, with characteristics or specifications that differ from those fuels generally sold, and which are derived from the recovery of effluents, side products or waste matter, whose combustion is not affected by environmental impact limitations (e.g. waste gas, bio-gas, biomass, etc.).
- The RITE includes as a novelty an *ITE 10.1*, entitled *Producción de ACS mediante sistemas solares activos*,[10] which specifically refers to low-temperature flat solar energy collectors for the heating of sanitary hot water installed at the building site.
- *ITE 10.2. Specific installations. Swimming pools*: According to these regulations, open-air swimming pools can only use waste/free, energy sources like solar energy for heating water.

(3) The creation of an Energy Certification for Buildings [21]. The *Energy Performance Certification* of a building is a certificate recognized by the State or a person designated by the State who verifies that the building is energy efficient on the basis of calculations established according to a specific methodology.
When buildings are constructed, sold, or rented, this certificate with a validity of up to 10 years is made available to the owner or purchaser of the building by the former owner.
This certificate gives objective information regarding the energy characteristics of the building to possible buyers or users. Consequently, it is conducive to greater transparency in real estate development and foments investments in energy-saving techniques.

4. Methodology

In order to carry out our study, we compiled statistics from 1996, which were obtained from the *Dirección General de Programación Económica de la Secretaría de Estado de Infraestructuras*,[11] an agency that depends on the *Ministerio de Fomento* or the Spanish Ministry of Public Works and Economy. The role of this Ministry in Spain is to propose and implement government policies concerning land, sea, and air transportation as well as their control, organization and regulation, the administration of postal and telegraphic services, the guidance and management of national agencies related to astronomy, geodetics, geophysics and cartography, and finally the planning and organization of all investments related to these areas [22].

[9] A national law in Spain is known as a royal decree [*Real Decreto* (*R.D.*)].
[10] Production of ACS with active solar energy systems.
[11] Government Office of Economic Planning of the Secretariat of Infrastructure.

The data for this study was obtained by using a questionnaire, on the basis of the construction licenses granted by the city halls. For the construction of new buildings, a license is necessary. Such a license can only be obtained by presenting the project design of the new building, which must be signed by the architect. Consequently, this is an administrative procedure that gives privileged information regarding the number and characteristics of buildings as well as the type of housing units that this construction generates [22].

The focus of this study is on residential buildings in construction. For our purposes, a *residential building* is defined as any permanent, separate, independent structure whose main purpose is to be occupied by people on a continuous basis (at least 50% of its useful surface with the exclusion of its ground floor and basement). A *house* is defined as an enclosed space or a set of various rooms and annexes that may occupy the entire surface of a building (one-family house) or part of a building, which in this case would be structurally separate and independent from the rest. A house is designed to be occupied by people, generally families of one or various members, and can be directly accessed from the public highway or from shared neighborhood spaces.

In Spain the *Ministerio de Fomento* collects data on a monthly basis for the whole country. The treatment of the response "no answer given" on certain questionnaires is handled by stratifying city halls in provinces by calculating expansion coefficients based on the city population and the number of licenses granted. The formula used is the following:

$$C_{ij} = P_{ij}/p_{ij} \cdot L_{ij}/l_{ij},$$

where C_{ij} is the elevation coefficient of stratum i in province j, P_{ij}, the population of the towns of stratum i in province j, p_{ij}, the population of the towns of stratum i in province j that have answered the questionnaire, L_{ij}, the number of licenses granted in stratum i in province j, l_{ij}, the number of licenses of stratum i in province j with questionnaires.

This expansion coefficient uses the first factor P_{ij}/p_{ij} to correct the refusal to answer, and L_{ij}/l_{ij} to correct the non-completion of questionnaires. In order to obtain the final results, questionnaires of each stratum-province are added up, and the resulting figure is multiplied by the coefficient. The size of the sample (i.e. the minimum number of towns that should be received from each stratum (n)), will depend on the total number of towns (N), the desired confidence level (K), the variability of the licenses granted (s), and the absolute error assumed for these licenses (e).

The formula used is the following:

$$n = N^2K^2S^2/(e^2 + NK^2S^2).$$

5. Results

The evolution of the number of housing units in Spain has undergone a spectacular increase in the last decade. During 1980–1997 an average of 287,000 houses were built each year [23]. From 1998, the number of houses constructed soared to over 400,000 a year (see Fig. 4).

There is currently a great risk of environmental degradation due to population increase, resource consumption, industrial activity, etc. This situation causes a series of problems such as acid rain or the hole in the ozone layer. Some of these problems are directly related

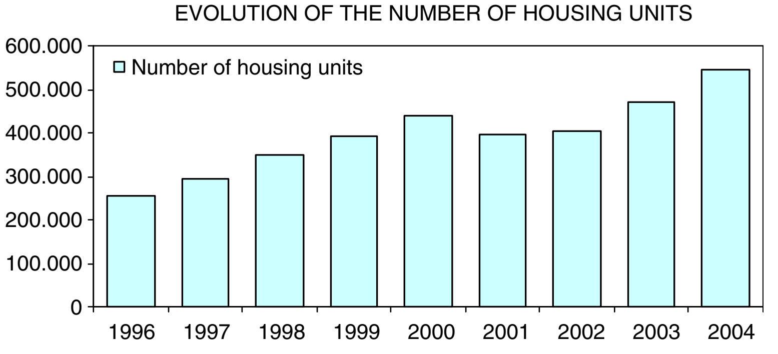

Fig. 4. Number of houses constructed in Spain. Data obtained from the *Ministerio de Fomento*.

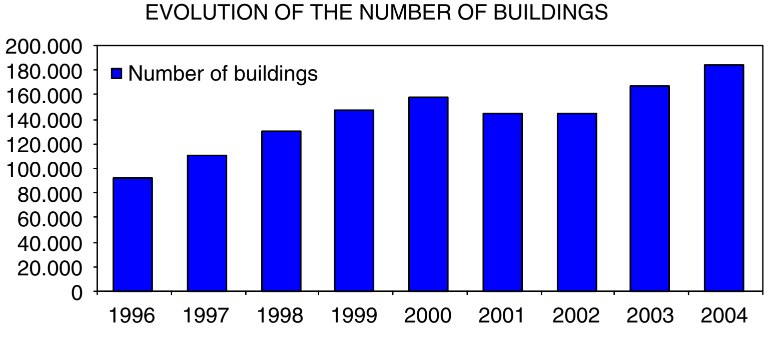

Fig. 5. Number of buildings. Data provided by the *Ministerio de Fomento*.

to substances sent into the atmosphere as a consequence of fossil fuel combustion or CFCs from air conditioning and cooling systems. Various authors suggest the use of renewable energies as a possible solution for such problems [24].

On the basis of the data obtained, we show the evolution of the number of buildings constructed in Spain, which has followed a progression similar to the number of housing units (see Fig. 5). This is due to the fact that the proportion of different types of houses (one-family houses, semi-detached house, and housing complex) is remarkably similar over this time period within the national context.

During this period, it is surprising what little use has been made of renewable energies in the construction sector. The data collected shows the number of buildings and the different types of energies employed: electricity, natural gas, liquid petroleum gas (LPG), and solar energy (see Fig. 6).

During the past decade, the total number of buildings with solar energy systems only reached 2.5%. Solar energy systems began appearing in new houses in 1996, and is now becoming increasingly more frequent (see Fig. 7). In 2004 the number of houses with this type of energy was 23,249 in contrast to 256 houses with this energy system in 1996.

If we compare annual variations of the different types of energy installed in buildings, we obtain the percentage of buildings per year that use a specific energy source (see Figs. 7, 8). The graph shows that there has been a relative decrease in the number of

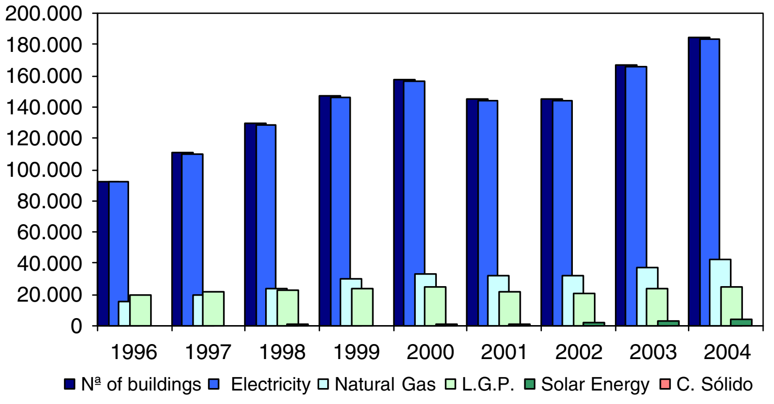

Fig. 6. Evolution of the number of buildings/type of energy system installed. Data obtained from the *Ministerio de Fomento*.

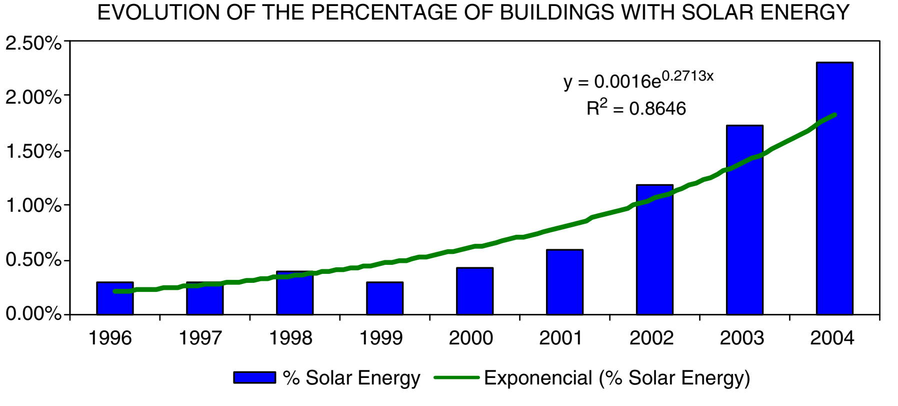

Fig. 7. Percentage (%) of buildings with solar energy.

buildings with energy systems fuelled by LPG. In contrast, there has been an important increase in the number of buildings that have installed natural gas and solar energy. The installation of systems using solid and liquid fuel remains constant.

The tendency curve over the last four years shows the progressive implementation of solar energy systems in residential buildings. As reflected in the graph, the number of buildings with this technology went from 0.3% to 2.4% in four years, which means a constant annual increase of 0.53 (see Fig. 9).

6. Conclusions

Spain is presently experiencing a spectacular construction boom. The number of new houses built reaches new records each year. However, despite the fact that the country has an annual average of 2515 h of sunlight, relatively little use has been made so far of the possibilities offered by solar energy systems in buildings.

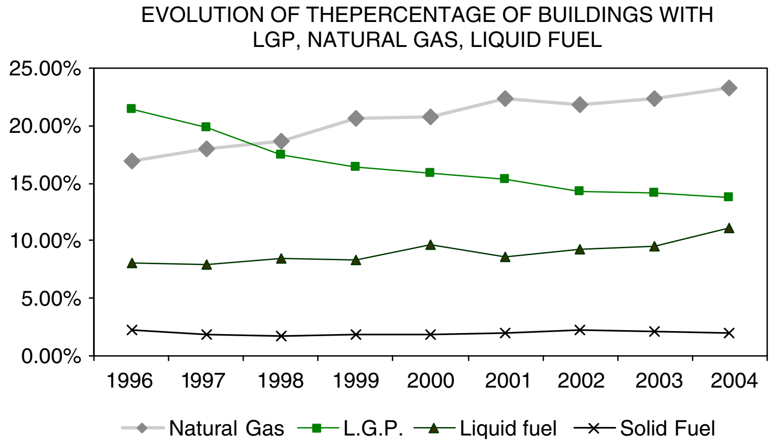

Fig. 8. Percentage (%) of buildings with different types of energy installed.

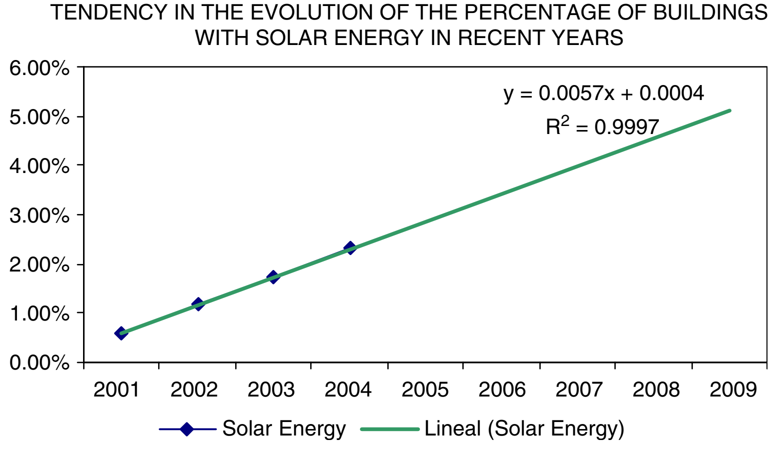

Fig. 9. Presence of solar energy in the construction sector.

In our opinion, the authorities have wasted too many years, and have thus lost an historic opportunity to foment and encourage the use of solar energy. Even though solar energy systems are gradually becoming more frequent in contrast to fossil fuel systems, whose growth rate was very low and even decreased in some cases, there is still much to be done.

The data collected in our study shows that although the use of solar energy is gradually on the upswing, recourse to this energy source is still infrequent. This signifies the urgent need for specific legal measures and government actions that will subsidize and/or require the use of this technology in order to encourage its use in new buildings.

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